SCIENCE FOR GLASS PRODUCTION

UDC 666.11.01:535.399

IMPROVING THE OPTICAL PROPERTIES OF FLOAT GLASS

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Translated from *Steklo i Keramika*, No. 11, pp. 3 – 5, November, 2006.

The nature of the defects that cause optical distortions in glass is analyzed. It was found that 70% of the optical defects in float glass is due to streak formation in the melt bath. Methods were developed for manufacturing float glass that increase its quality with respect to the optical indexes.

Improving the optical properties of float glass is caused by the necessity of having the quality indexes of glass for export satisfy the requirements of European standard EN 572-2 and by growth of the internal market for glass with elevated optical properties. Such indexes as varying thickness, waviness, strias, nonflatness, sag, streakiness, micrononflatness, lamination, nips, and surface ripples affect optical distortions in sheet glass. We considered deviations of these indexes from the acceptable values in GOST 111–2001 as optical defects.

There are almost no studies that describe the correlation between optical defects and process parameters in production of float glass in the research conducted by different investigators.

The analysis of the statistical data on optical defects in heat-absorbing glass processed on an ÉPKS-4000 line showed that 70% of them contained defects related to glass ribbon formation in the melt bath; 46% concerned defects on the top surface and 24% involved the bottom surface (Fig. 1). For this reason, studies to reveal the correlation of the production process parameters and optical properties of float glass are of great interest.

Angle Z, which is determined by the Zebra method, was selected as the criterion for evaluating the optical properties of the float glass. This method can be used to evaluate optical distortions caused by all of the defects listed above.

The statistical distribution of angle Z by the width of the glass ribbon manufactured on an ÉPKS-4000 float line is represented in differential curves in Fig. 2. It was found that the existing technology allows obtaining float glass with a large angle Z (50° and more). The individual sections of the glass ribbon with Z equal to 50° indicate the high optical homogeneity of the glass melt fed into the tin melt for shaping the glass into a ribbon. There is important inhomogeneity of the value of angle Z over the width of the glass ribbon, which could be due to different causes.

We know that the cause of the decrease in the optical indexes in edge sections of a glass ribbon of thick nominal values (8 mm and more) near the edges is adhesion of the glass melt to the limiters that prevent transverse spreading (FRG Patent No. 1596597, USA Patent No. 3674456). To prevent adhesion, the limiters oscillate. However, the shock effect of the limiters on the end surface of the edges of the formed glass ribbon causes deformation of the sections near the edges and correspondingly worsening of the optical properties of the glass.

To prevent deformation of the sections near the edges of glass of thick nominal values, we developed a method of

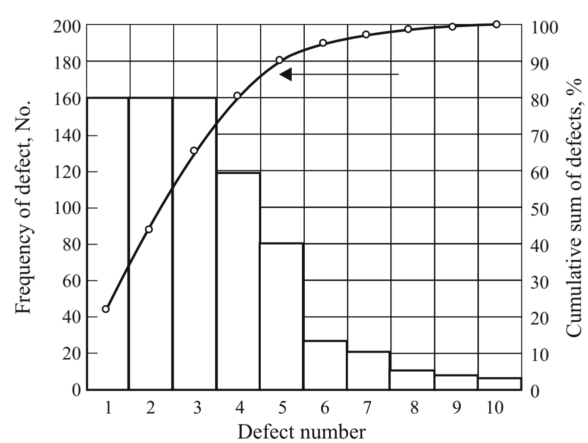

Fig. 1. Pareto diagram for types of optical defects in glass: *1*) rippled surface; *2*) buckling; *3*) micrononflatness; *4*) streakiness; *5*) strias; *6*) macrononflatness; *7*) varying thickness; *8*) sag; *9*) nips; *10*) lamination.

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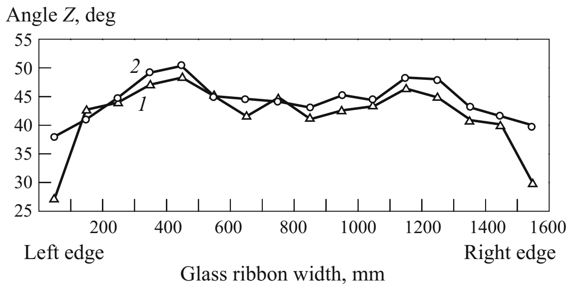

Fig. 2. Distribution of angle Z by width of glass ribbon 4 mm (*1*) and 6 mm (*2*) thick.

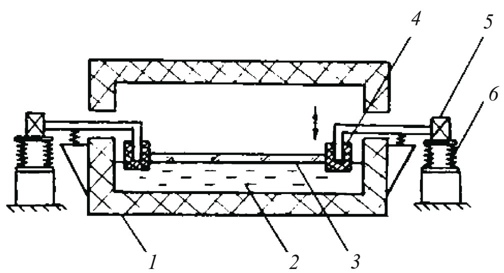

Fig. 3. Cross section of a melt bath with limiters: *1*) bath; *2*) metal melt; *3*) glass ribbon; *4*) limiters; *5*) vibrators; *6*) system of springs.

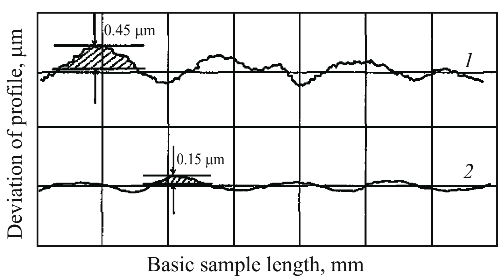

Fig. 4. Profilograms of the top surface of glass processed on an ÉPKS-4000 float line using (*1*) and not using (*2*) BM.

eliminating shock effects on the ends of the formed ribbon. The limiters slide back and forth over the end surface of the glass ribbon in the proposed method (Fig. 3).

Moreover, in processing glass of thin face values (4 mm and less) using beading machines (BM), there is also the problem of decreasing the optical indexes in the sections near the side of the glass ribbon. The profilograms in Fig. 4 show that glass processed with the BM has coarser relief in the sections near the sides than directly drawn glass (without using the BM).

In addition, the decrease in the optical indexes of the upper surface of the glass ribbon could be caused by convection currents of the protective atmosphere in the gas space of the melt bath. When there is a large temperature difference between the hot and cold ends of the melt bath, the gas velocity at the surface of the glass is high enough to actively cool it

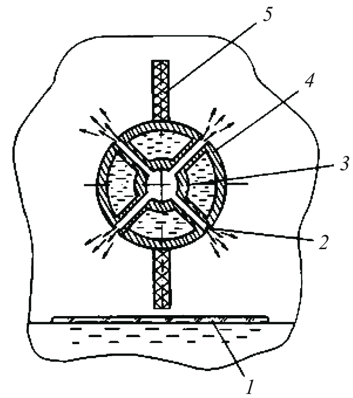

Fig. 5. Barrier over gas space with perforated tube: *1*) glass ribbon; *2*) channels for discharge of protective gas; *3*) perforated tube; *4*) water-cooled beam; *5*) partition.

due to convective heat exchange. Cooling in the hot zone of the melt bath can be so intensive that the surface layer of glass becomes more viscous than the internal layers of the glass ribbon. As a result of this, compressive stresses arise on the surface of the glass and cause formation of optical distortions in the form of surface microroughness (British Patent No. 1122871, US Patent No. 3630705).

This problem becomes especially acute for short melt baths such as the ÉPKS-4000 minifloat unit.

Special barriers are used to regulate convection currents in the gas space of the melt bath (US Patents Nos. 3351451, 3860406), but they do not make it possible to regulate the gas currents circulating in the immediate vicinity of the surface of the glass due to the gap formed between the barrier and its surface.

To regulate the gas currents in the melt bath, we proposed a rotating barrier which would allow cutting off the cold currents of the protective atmosphere circulating in the immediate vicinity of the surface of the glass (Fig. 5).

When the barrier installed after the thinning machine rotates, the current of previously heated gas going out through the tube opening moves clockwise near the surface of the gas simultaneously in two opposite directions. At low barrier rotation rates, the gas going out of the tube forms laminar gas currents that cut off the cold convection current directed on the glass ribbon before the thinning machines so that the compressive stresses in the surface layer of this part of the glass ribbon decrease and the microroughness of the top surface of the glass is correspondingly smoothed.

An experimental batch of glass was manufactured on the ÉPKS-4000 float line; the barrier was installed in the high-temperature zone of the melt bath. The average indexes for the quality of initial and experimental glass are reported in Table 1.

It was found that the thickness nonuniformity of the glass decreased by 1.5 – 2 times and the fluctuations did not exceed ± 0.01 mm; the height of microroughnesses on the upper surface of the glass, measured with a Sakura interfe-

TABLE 1

Thickness of glass, mm		Width of ribbon with sides, mm	Thickness nonuniformity, mm	Angle Z, deg	Raster, mm, with edges*	Micrononflatness, μm		
						left side	center	right side
Initial	5	1836	0.06	40 – 45	8	46.0	25.5	50.0
	6	1806	0.09	40 – 45	7			
Experimental	5	1816	0.03	45 – 50	6	19.8	17.8	24.0
	6	1798	0.08	45 – 50	7			

* The raster without sides was 4 mm.

rometer, decreased by 1.4 times in comparison to the initial glass; fluctuations in the glass ribbon width decreased by 4 times in comparison to the initial glass. In addition, the homogeneity of the top surface layer of glass increased. Thin laminar layers in the immediate vicinity of the top surface of the experimental glass were examined in the microscope at magnification of more than 60 times, while the surface layer of the initial glass were observed at magnification of less than 20 times.

The possibility of improving the optical properties of float glass by introducing constructive changes in the melt bath process equipment is thus very real.